PB87-129300

Seasonal Variability in Prickly Pear Creek Water Quality and Macroinvertebrate Communities

Lockheed Engineering and
Management Services Co., Inc., Las Vegas, NV

Prepared for

Environmental Monitoring Systems Lab.
Las Vegas, NV

Dec 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-129300
EPA/600/2-86/104
December 1986

SEASONAL VARIABILITY IN PRICKLY PEAR CREEK WATER QUALITY AND MACROINVERTEBRATE COMMUNITIES

by

Barry P. Baldigo,[1] John R. Baker,[1] Wesley L. Kinney,[2] and Mike Fillinger[3]

[1]Lockheed Engineering and Management Services Co., Inc.
1050 East Flamingo Road
Las Vegas, Nevada 89109

[2]U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

[3]Environmental Investigations Services, Co.
Helena, Montana 59601

EPA Contract 68-03-3249
Job Order 20.04

Technical Monitor

Wesley L. Kinney
Advanced Monitoring Systems Division
Las Vegas, Nevada 89114

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
LAS VEGAS, NEVADA 89114

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/2-86/104		PB87 129300/AS

4. TITLE AND SUBTITLE
SEASONAL VARIABILITY IN PRICKLY PEAR CREEK WATER QUALITY AND MACROINVERTEBRATE COMMUNITIES

5. REPORT DATE
December 1986

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Barry P. Baldigo[1], John R. Baker[1], Wesley L. Kinney[2], and Mike Fillinger[3]

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Lockheed Engineering & Management Services Co., Inc.
1050 East Flamingo Road, Las Vegas, NV 89109
Environmental Investigations Services Co.
Helena, MT 59601

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-03-3249

12. SPONSORING AGENCY NAME AND ADDRESS
Environmental Monitoring Systems Laboratory - LV, NV
Office of Research and Development
U.S. Environmental Protection Agency
Las Vegas, NV 89114

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
EPA/600/07

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Prickly Pear Creek, Montana, was sampled during four seasons in 1982 and 1983 to attempt to relate biological responses to fluctuations in discharge, in-stream toxicity and metal concentration in the water column. The biota (macroinvertebrate) were definately impacted directly downstream from a metal source during all seasons, but no definate relationships among discharge, metal concentration and biological response could be established on a seasonal basis.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	44
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under contract 68-03-3249 to Lockheed Engineering and Management Services Co., Inc. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

CONTENTS

I. INTRODUCTION 1

II. STUDY AREA 4

III. METHODS. 8

Water Quality. 8
Hydrology. 9
Macroinvertebrates 10

IV. RESULTS. 11

Water Quality. 11
Hydrology. 20
Macroinvertebrates 20

Control Zone (Station 011). 20
Spring Creek (012). 26
Impact Zone (Stations 013 and 014). 26
Recovery Zone (Station 018) 28

V. DISCUSSION 29

VI. CONCLUSIONS. 34

VII. REFERENCES 36

TABLES

Number		Page
1	Location of Stations on Prickly Pear Creek and Spring Creek, Montana, 1983, With a Cross Reference to 1982 Stations.	6
2	Total Metal Concentrations From Prickly Pear Creek and Spring Creek Sites During the Four Sampling Periods.	12
3	Discharge Estimates and USGS Data for Prickly Pear Creek and Spring Creek During the Four Sampling Periods	22
4	Mean Invertebrate Community Indices From Prickly Pear Creek During the Four Sampling Periods.	23

FIGURES

Number		Page
1	Station locations on Prickly Pear Creek, Montana	5
2	Mean total lead concentrations at each station during the four survey periods.	13
3	Mean total silver concentrations at each station during the four survey periods.	14
4	Mean total arsenic concentrations at each station during the four survey periods.	15
5	Mean total cadmium concentrations at each station during the four survey periods.	16
6	Mean total zinc concentrations at each station during the four survey periods	17
7	Mean total copper concentrations at each station during the four survey periods.	18
8	Mean monthly discharge for Prickly Pear Creek, Montana, from December 1982 through October 1983, and measured discharge at the USGS gauge downstream from station 018 during each survey period.	21
9	Total number of taxa collected at each station during the four survey periods.	24
10	Mean total number of individuals collected at each station during the four survey periods	25

I. INTRODUCTION

Prickly Pear Creek, Montana, was studied by the U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV), during the summer of 1980. Prickly Pear Creek was one of 15 streams examined in which concentrations of toxic metals exceeded the EPA's aquatic life water quailty criteria (U.S. EPA, 1980). This stream was of particular interest because although concentrations of zinc, copper and cadmium exceeded the acute aquatic life criteria several fold, healthy biota were observed throughout much of the system (Miller et al., 1982). During 1981 and 1982, additional surveys and on-site toxicity tests were conducted to investigate factors that enable sensitive organisms to tolerate exposure to waters containing concentrations of metals well in excess of acute national aquatic life criteria. Toxicity tests conducted in 1981 indicated that some resident species were able to acclimate to sublethal metal concentrations (Miller et al., 1986); however, during 1982, La Point et al. (1983) observed no significant difference in sensitivities between hatchery reared and resident brook trout. Additional studies were conducted during 1983 to examine persistence and degradation of metal toxicity in Prickly Pear Creek as revealed by the downstream distribution of toxic metals and the resultant response of the resident biota (Baker and Baldigo, 1984). Study results indicated that metal toxicity behaves conservatively; hence, its downstream distribution can be predicted by a steady state, mass balance model that explains toxicity reduction through dilution.

The studies cited above and others (Mount et al., 1984; Spehar and Carlson, 1984) have identified factors that affect organism-ecosystem toxic responses. However, not all factors are equally influential in all aquatic systems, and it is important to be able to identify the principal factors controlling metal availability and toxicity in a given system. Such information is essential for purposes of designating water uses, establishing aquatic life water quality criteria on a site-specific basis, and for issuing permits for a particular discharge and receiving water.

One factor that has generally been ignored in relating metal concentrations to in-stream toxicity and biological responses is seasonal variability in flow and associated changes in water quality and in the biota. In some waterways, depending upon the sources of metal contamination and the particular chemical and physical characteristics of a watershed and receiving stream, toxicity may be greatest during periods of high flow when metals are most susceptible to mobilization and transport to surface water (e.g., streams receiving drainage from mine tailings). Conversely, in the same system during low flow periods, metal loading to the stream may be minimal, and the toxicity may be greatly reduced. On the other hand, streams receiving a relatively constant metal load independent of runoff (e.g., an industrial effluent) may show greatly reduced toxicity during periods of high flow because of the dilution and the sorption of metals by suspended and dissolved solids. Such systems typically are most toxic during low flow periods when the solids load is lowest and when metal concentrations and water temperatures are highest. Knowledge of these factors is crucial to enable water managers to make intelligent decisions regarding the issuance of permits, the allocation of waste loads, the designation of benefical uses, and the establishment of site-specific criteria and standards.

The need to examine seasonal variability in the toxicity of receiving streams was recognized by La Point et al. (1984) and Miller et al. (1986). Consequently, a study was conducted on Prickly Pear Creek to assess seasonal variability in discharge, in water quality, and in the biota. The remainder of this report addresses that study.

II. STUDY AREA

Prickly Pear Creek forms its headwaters in the Elkhorn Mountains approximately 32 km southeast of Helena, Montana (Figure 1). The stream flows north for 64 km before entering Lake Helena and the Missouri River. Gold mining in the Corbin and Spring Creek drainage basins began in the early 1860's. Tailing and settling ponds remain as prominent features within these drainages and release high concentrations of zinc, copper, and cadmium which are carried into Prickly Pear Creek via Spring Creek. Prickly Pear Creek also underwent extensive mining operations in the early 1900's. The Montana Water Quality Bureau (1981) reported over 75 percent of Prickly Pear Creek was subjected to streambed modifications and to dredging during the mining process.

The present study reach was generally characterized by continuous riffle flow interspersed with distinct pools. The substrate was primarily cobble and gravel throughout. The Prickly Pear Creek annual discharge at the U.S. Geological Survey (USGS) gaging station (Figure 1) ranged from 30 to 343 cubic feet per second (cfs) with a mean of 55 cfs during the 1982 to 1983 water year. (unpublished USGS data). Spring Creek discharge during this study ranged from approximately 1 to 5 cfs.

Four principal stations on Prickly Pear Creek and one station on Spring Creek were utilized in this study (Table 1). Spring Creek was considered an "effluent" site (012). Station 011, upstream from the confluence of Spring Creek and Prickly Pear Creek, was used as a control. Stations 013 and 014 were

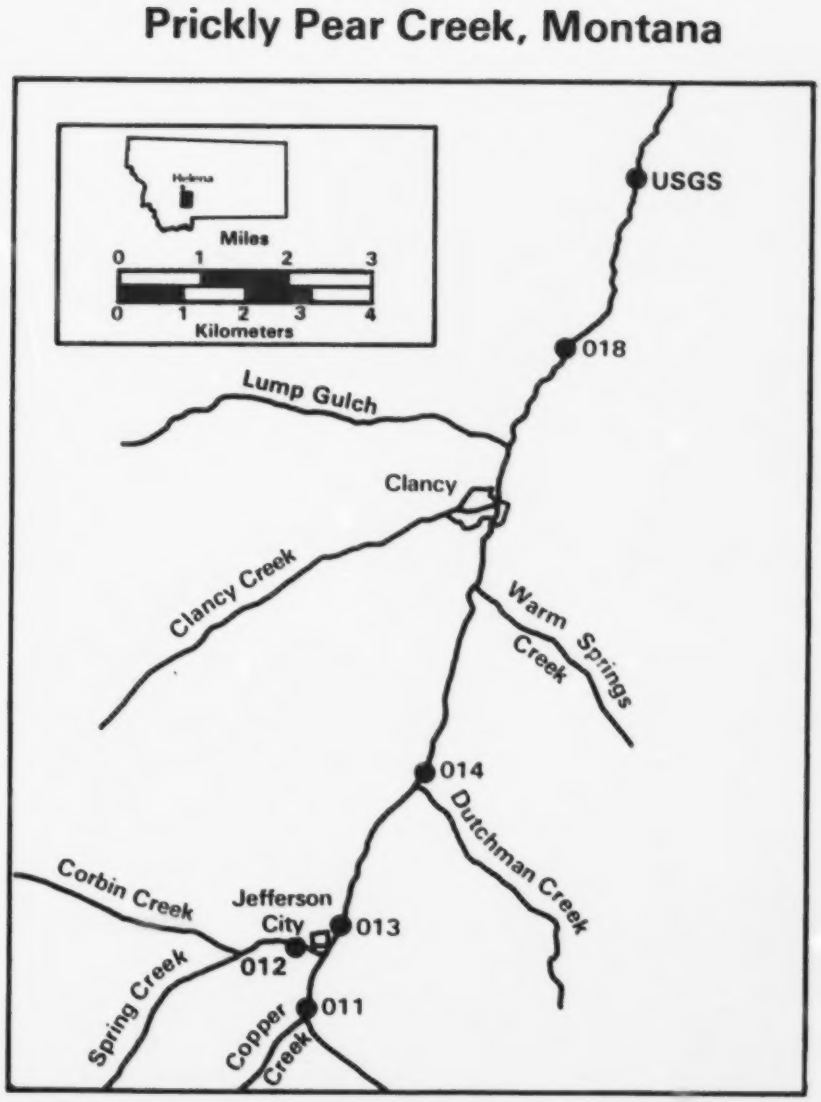

Figure 1. Station locations on Prickly Pear Creek, Montana.

TABLE 1. LOCATION OF STATIONS ON PRICKLY PEAR CREEK AND SPRING CREEK, MONTANA, 1983, WITH A CROSS REFERENCE TO 1982 STATIONS (La Point et al., 1983)

1983 Station No.	Description	1982 Station No.
011	Prickly Pear Creek, 1.1 km upstream from Spring Creek confluence	0111
012 (Spring Creek)	Spring Creek, 100 m upstream from Spring Creek confluence	012
013	Prickly Pear Creek, 300 m downstream from Spring Creek confluence	0133
014	Prickly Pear Creek, 3.8 km downstream from Spring Creek confluence, 100 m downstream from Dutchman Creek confluence	0142
018	Prickly Pear Creek, 12 km downstream from Spring Creek confluence, 3 km downstream from Lump Gulch confluence	017

designated impact zone sites, and Station 018 (and occasionally 014) was designated as a downstream recovery zone site.

III. METHODS

Invertebrate populations and stream water metal concentrations from Prickly Pear Creek control, impact, and recovery sites were sampled during 1982 and 1983. Collections were undertaken during separate seasons to assess variations in discharge, temperature, runoff, metal concentrations, and invertebrate communities. Sampling was conducted from December 21 to 23, 1982, from April 7 to 9, 1983, and from October 11 to 13, 1983. Data from a separate survey conducted by La Point et al. (1983) from July 18 to 26, 1982, are also included to provide information on summer conditions. Water samples were also collected from Spring Creek during all seasons, however, invertebrate samples were only taken during July 1982. Commonly measured water quality parameters, namely, DO, conductivity, pH, temperature, and turbidity, were recorded during the surveys but are not included in this report. All values for these parameters were within acceptable limits for high quality trout streams of the region.

WATER QUALITY

During July 1982, water for metals analyses was collected in triplicate 500 ml grab samples at each station (La Point et al., 1983). Because very little varability among replicates was observed in these samples for copper and zinc, the most prominent toxic metals in the stream, during December 1982 and April 1983, single water samples were collected from each station for metal

analyses. October 1983 metals data were compiled from individual grab samples collected from each station on 10 consecutive days (Baker and Baldigo, 1984). All metal samples were preserved with Ultrex grade HNO_3 to pH $\leq$2.0. July 1982 samples for metals analyses were shipped to the Laboratory of Biomedical and Environmental Science located at the University of California at Los Angeles (UCLA) for Inductively Coupled Plasma Optical Emission Spectrometric (ICP) analysis of trace elements (U.S. EPA, 1979; Alexander and McAnulty, 1981). The detection limits of UCLA's ICP for all metals except zinc and copper approached or exceeded ambient levels in the water column, during July 1982 (La Point et al., 1983). Hence, the July data for cadmium, lead, silver and arsenic should be viewed with this in mind. Metal analyses for the other three periods were conducted by Lockheed-EMSCO, Las Vegas, Nevada, using more sensitive apparatus and methods. Zinc and copper were analyzed by AA Flame; cadmium, lead, and arsenic via AA Furnace; and silver via ICP. The sensitivity, detection limits, precision, and accuracy of the Lockheed-EMSCO analytical techniques are presented in U.S. EPA (1983).

HYDROLOGY

Stream discharge was measured at each station during the July and October surveys using a Marsh-McBirney Model 57 current meter. At each station flow at each of 20 intervals along a transect was measured at 6-tenth depth. Multiplying depth, width, and velocity at each interval and summing across all intervals estimates total discharge. Results obtained with this method are reliable when water depth is between 0.09 and 0.76 meters (USGS, 1980). Annual discharge data were obtained from USGS provisional unpublished data, water years 1981 to 1983.

The December 1982 and the April 1983 discharge was extrapolated from July and October data and from USGS gauge values for these periods taken about 3 km downstream from Station 18.

MACROINVERTEBRATES

A Portable Invertebrate Box Sampler (PIBS) (Rutter-Ellis Associates, 1973) was used to collect samples from riffle zones of uniform flow and velocity. The net on the PIBS sampler was constructed of Nitex 585 μm (approximately U.S. Standard 30 mesh) cloth. Five replicate samples were collected from each station. Samples were preserved in 10 percent formalin and returned to the laboratory for processing. Animals were removed from preserved samples by scanning the sample in a shallow white pan until no macroinvertebrates were observed in the sample for a 1 to 2 minute continuous scanning period. Each sample was examined by another person using the same procedure as a quality control measure. Sorted invertebrates were identified to the lowest possible taxonomic level and counted. Invertebrate identifications and counts were recorded on bench sheets, entered into computer storage, and tabulated for inclusion in the appendices. A reference collection of identified specimens is maintained at EMSL-Las Vegas.

Standard indices of macroinvertebrate community structure (richness, evenness, dominance, diversity, and mean count data) are presented. More extensive data and interpretation of the July 1982 macroinvertebrate communities are provided in La Point et al. (1983).

IV. RESULTS

WATER QUALITY

Data for metals of concern in Prickly Pear Creek, i.e. cadmium, lead, zinc, copper, silver, and arsenic, are summarized in Table 2. This table and Figures 2, 3, 4, and 5 suggest that lead, silver, arsenic, and cadmium contamination during July 1982 did not originate from Spring Creek because control Station (011) concentrations exceeded those of the effluent (012) and/or the receiving stream impact zones (sites 013 and 014). This apparent anomaly is probably attributed to analytical limitations of the ICP instrument used for analyses of the July 1982 samples. During the other sampling periods more sensitive analytical methods indicated that water column concentrations of lead, silver and arsenic were low, well below the national water quality criteria for aquatic life. The three metals that commonly exceeded National Criteria during all seasons were cadmium (Figure 5), zinc (Figure 6), and copper (Figure 7), (La Point et al., 1983). Hence, these results concentrate principally on these metals.

Cadmium levels in July of 1982 (Table 2, and Figure 5) appeared elevated over those which occurred during the other three periods, but were undoubtedly a function of the different analytical methods. The cadmium values reported during this period approached the detection limits of the ICP instrument used for these analyses (La Point et al., 1983, Alexander and McAnulty, 1981).

TABLE 2. TOTAL METAL CONCENTRATIONS FROM PRICKLY PEAR CREEK AND SPRING CREEK SITES DURING THE FOUR SAMPLING PERIODS

	Date	011	012	013	014	018
Cadmium	07/22/82	13	17	19	10	10
	12/21/82	0.2	5.4	2.4	0.7	0.3
	04/08/83	<.3	6.0	2.6	0.9	0.2
	10/09/83	2.0	7.6	5.0	4.0	3.0
Lead	07/22/82	64	29	119	52	51
	12/21/82	2.4	242.5	84.3	16.4	8.6
	04/08/83	<1	246.6	66.1	18.1	5.7
	10/09/83	13	72	30	19	15
Zinc	07/22/82	71	2227	454	221	128
	12/21/82	21.9	1128	431.1	212.2	134.5
	04/08/83	40.5	1595	640.7	320.9	138.4
	10/09/83	100	2119	580	236	203
Copper	07/22/82	20	119	33	13	15
	12/21/82	<9	80.7	37.0	22.0	13.0
	04/08/83	11.0	67.8	25.3	11.7	<9
	10/09/83	12.0	84	28	14	12
Silver	07/22/82	25	24	9	6	4
	12/21/82	<7	<7	<7	<7	<7
	04/08/83	<7	<7	<7	<7	<7
	10/09/83	0.6	1.6	1.9	0.2	0.1
Arsenic	07/22/82	163	90	87	61	126
	12/21/82	<2	46.4	16.7	4.0	5.3
	04/08/83	<2	26.9	10.3	4.5	5.0
	10/09/83	<2	27	6	4	10

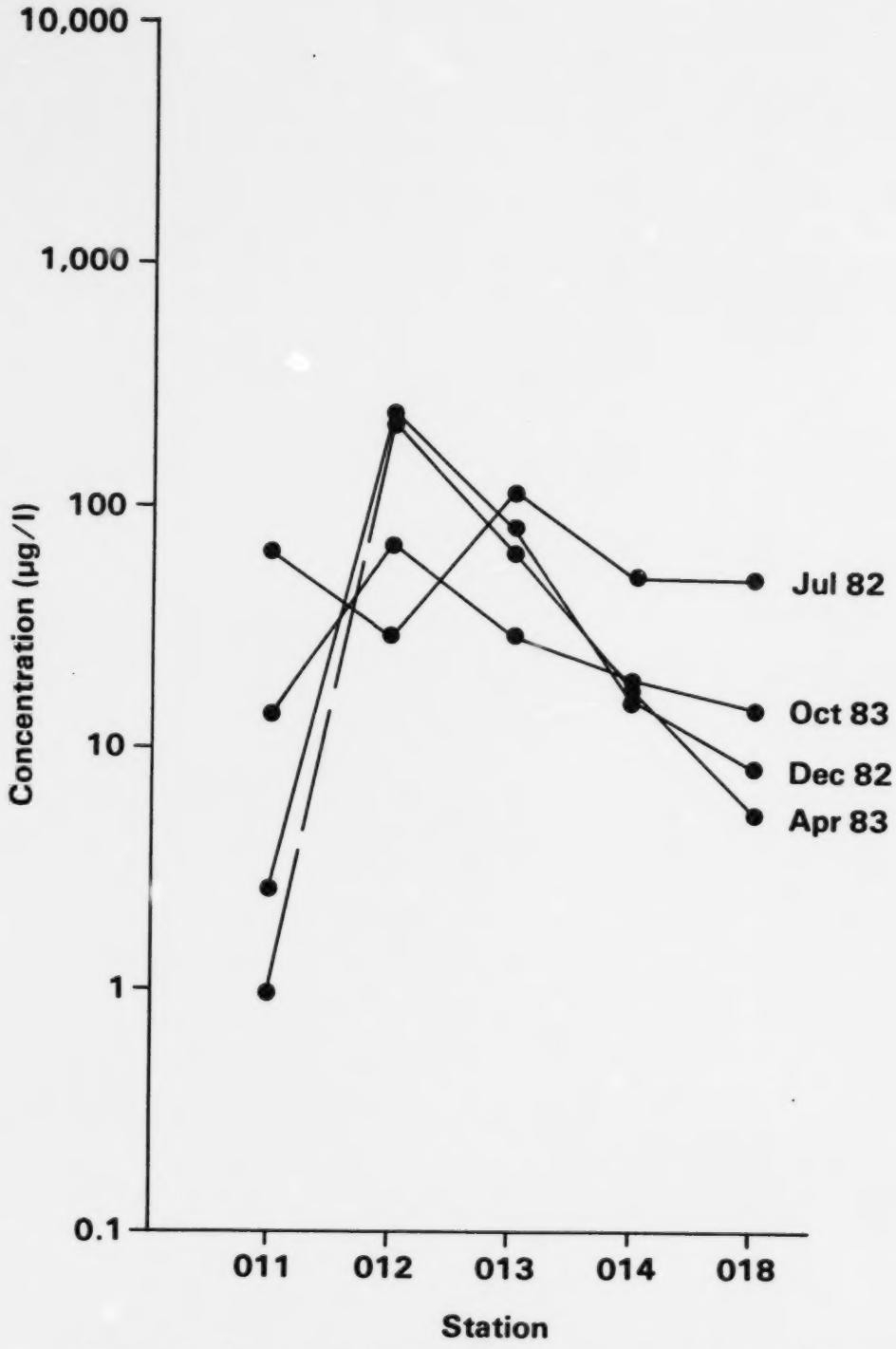

Figure 2. Mean total lead concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

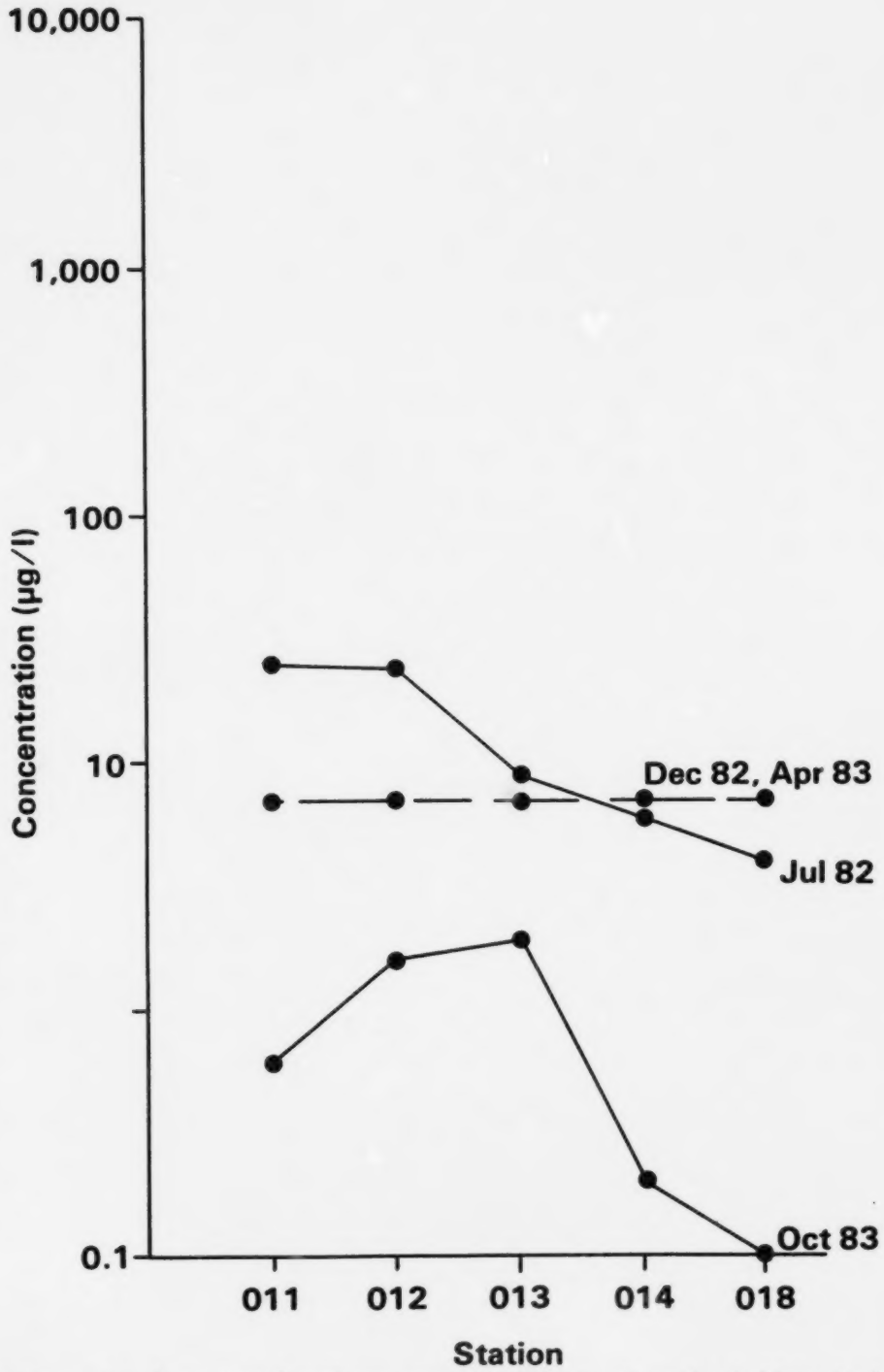

Figure 3. Mean total silver concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

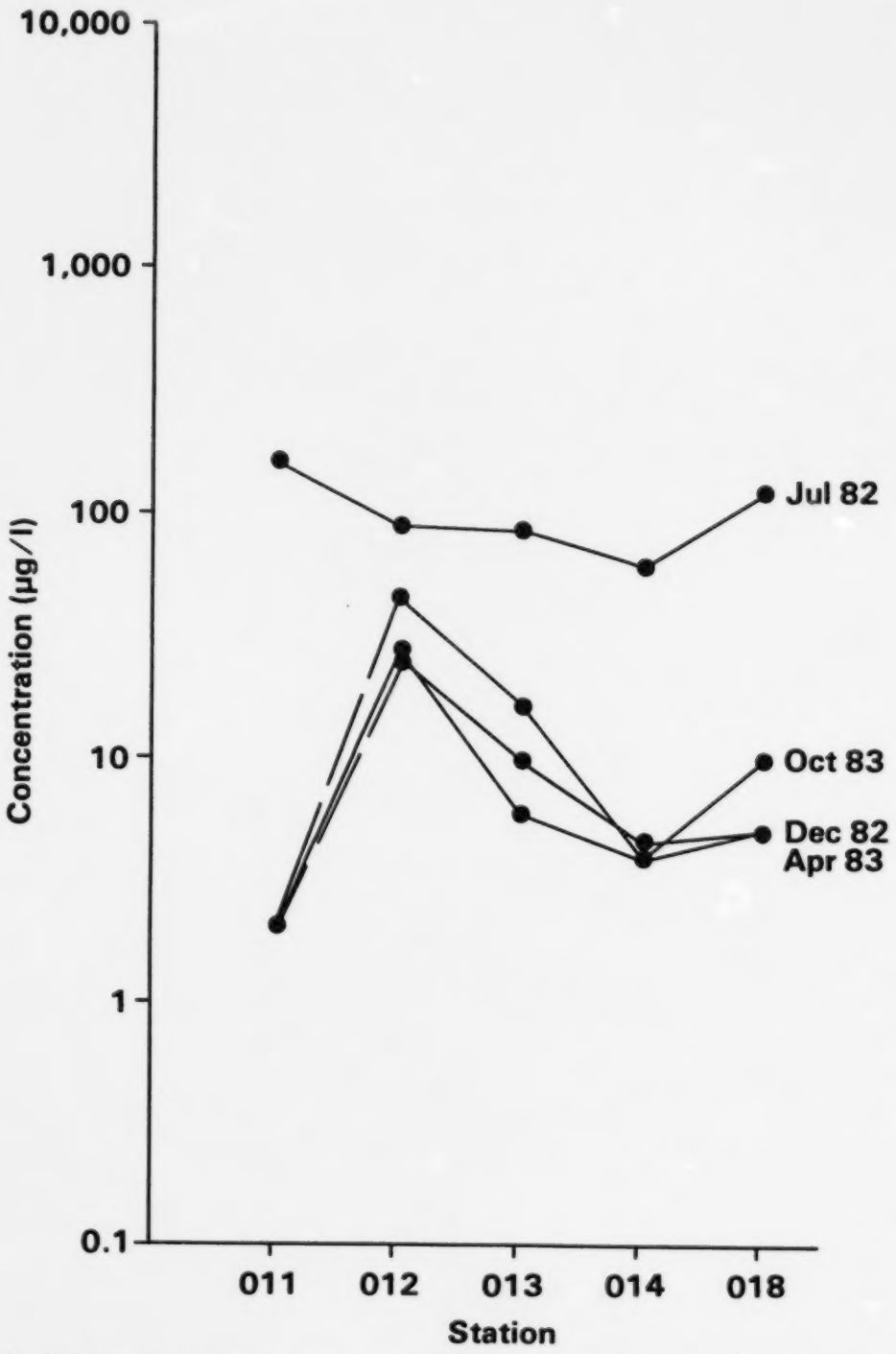

Figure 4. Mean total arsenic concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

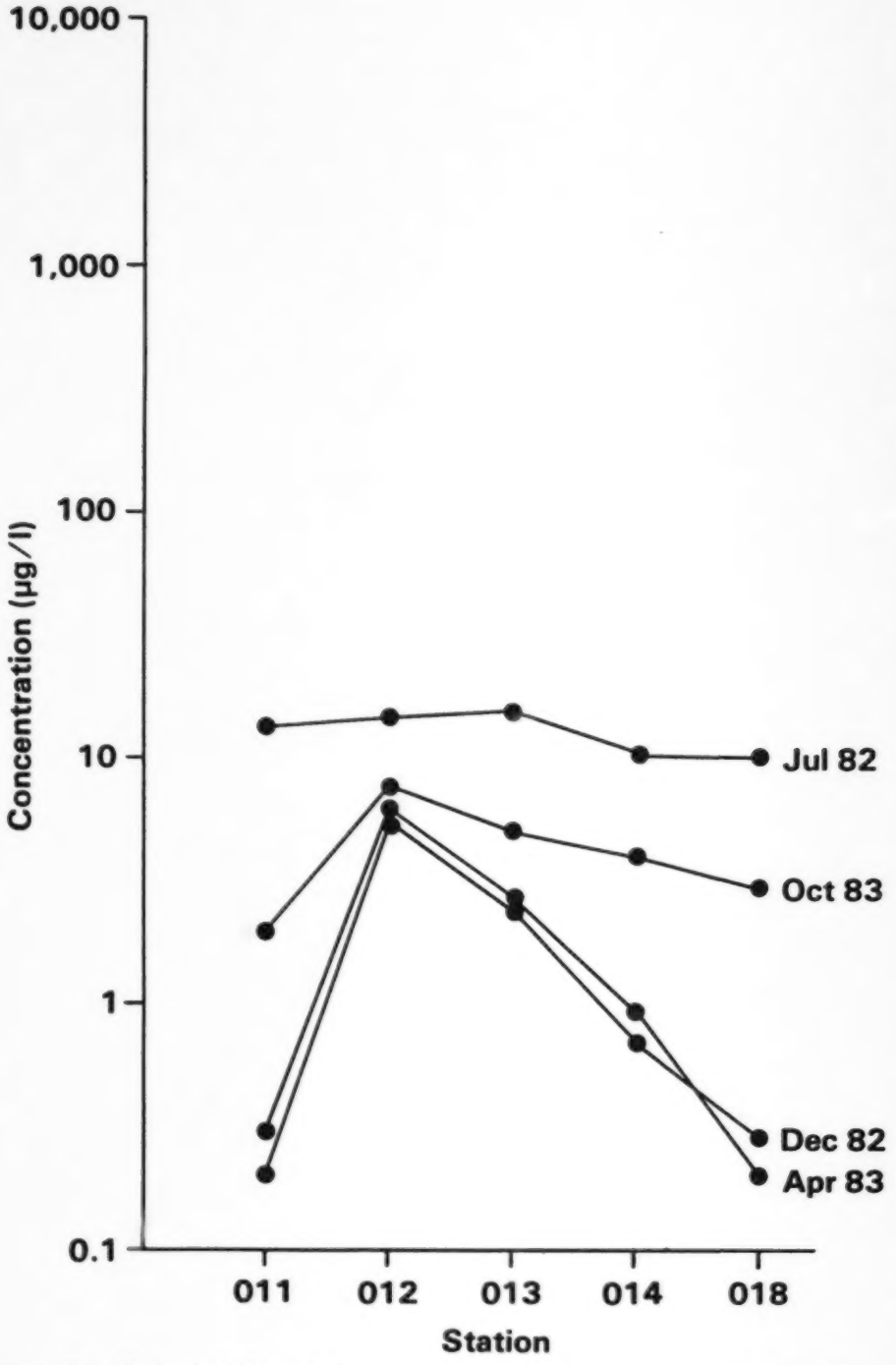

Figure 5. Mean total cadmium concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

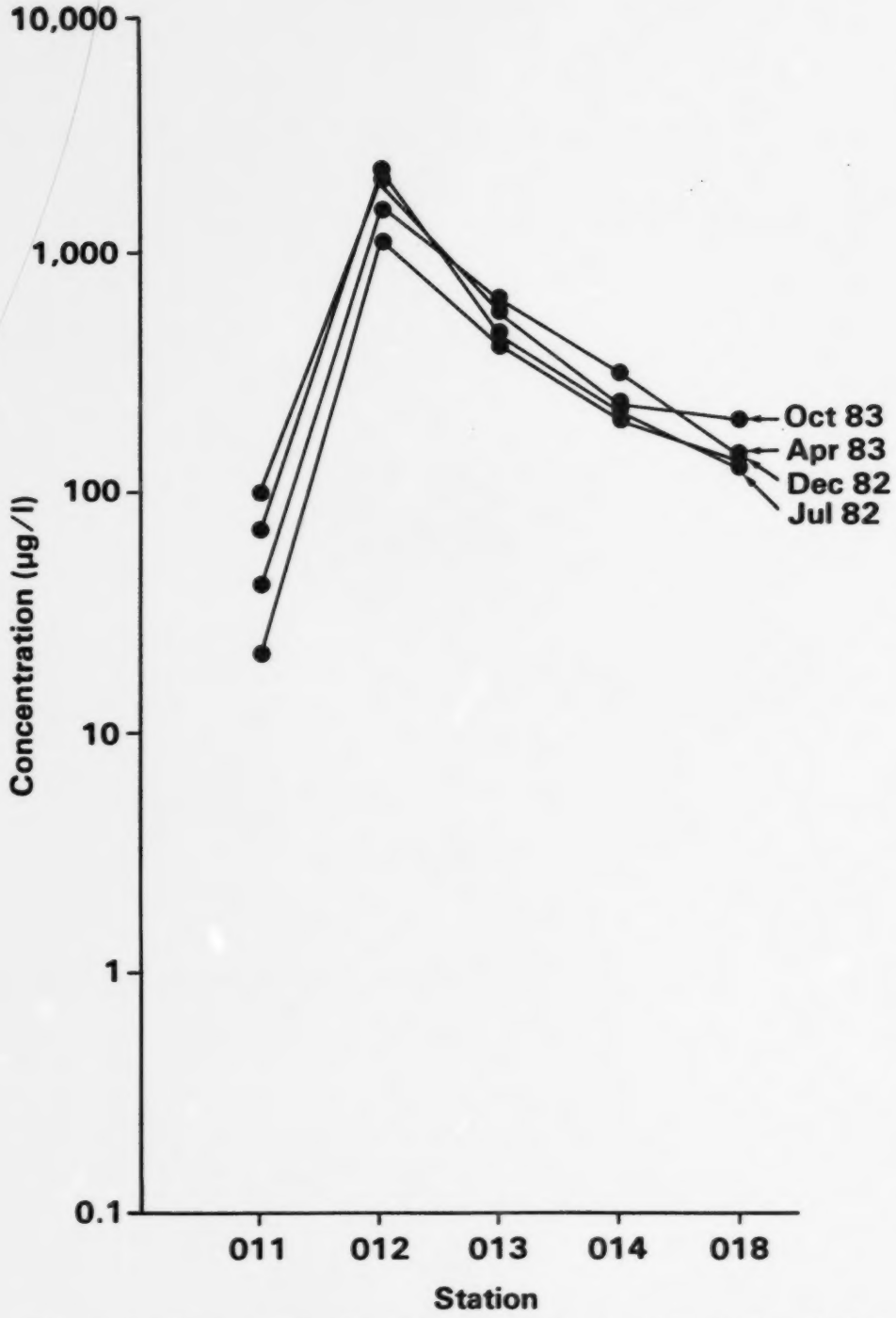

Figure 6. Mean total zinc concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

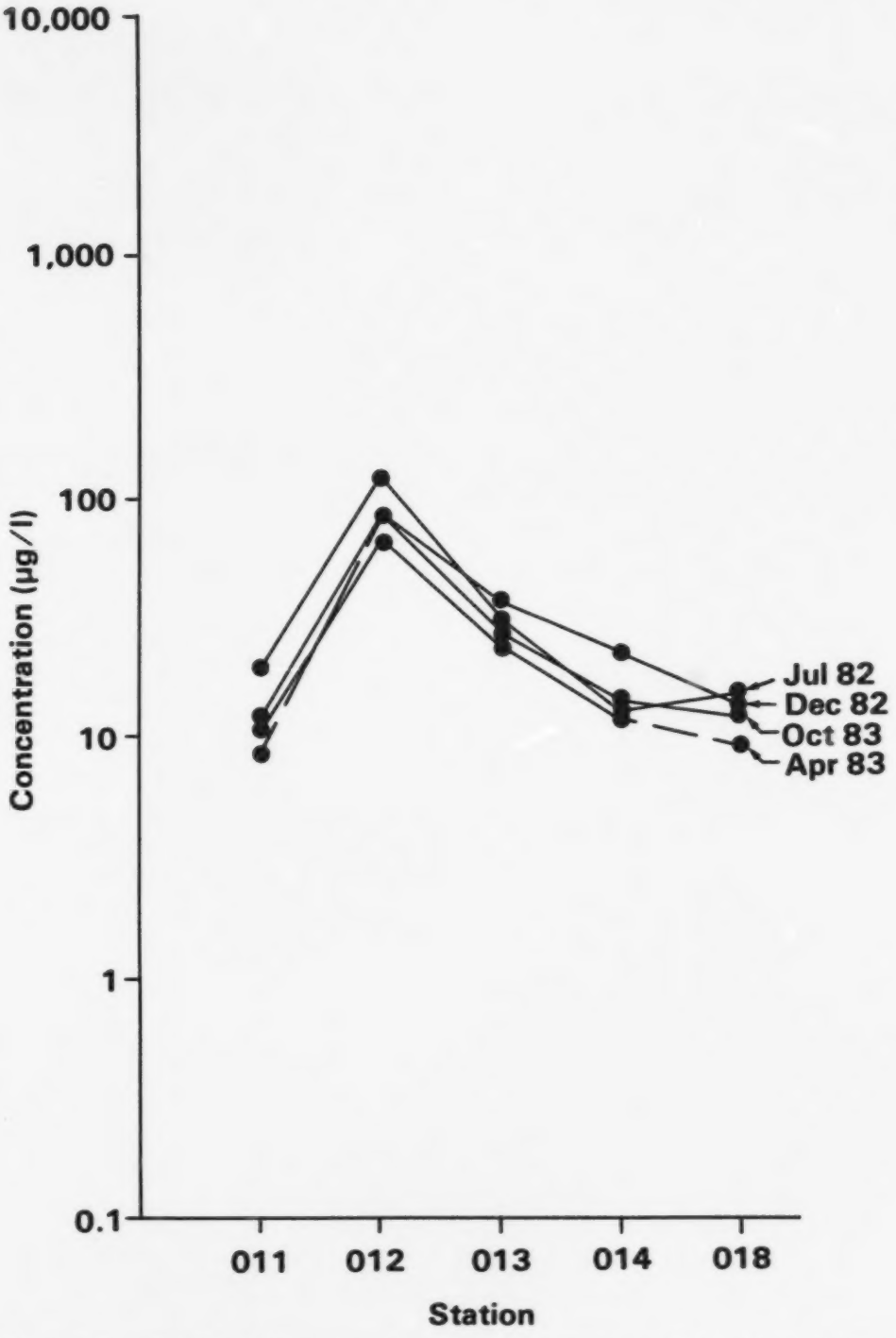

Figure 7. Mean total copper concentrations at each station during the four survey periods. Dashed lines indicate one or more data points are at or below the detection limit.

However, cadmium concentrations were clearly elevated in Spring Creek and impact Station 013 over the other stations during the other seasons as well with levels well above the control concentrations. Spring Creek produced elevated levels of cadmium in Prickly Pear Creek impact site 013, but a gradual reduction to near control (011) levels was observed at sites 014 and 018 (Table 2). The highest concentrations at all stations (excluding July 1982) occurred in October 1983 during low flow. April (1983) and December (1982) concentrations were considerably lower at the downstream sites (014, 018) than summer and fall values. Correlation analysis of USGS gauging station discharge data (see Hydrology results) and cadmium concentrations produced correlation coefficients at sites 012 and 018 of $r = 0.94$ and $r = 0.93$, respectively.

Very high zinc levels in Spring Creek (1128 to 2227 µg/l) resulted in substantial increases in zinc concentrations in Prickly Pear Creek (Table 2, Figure 6, and La Point et al., 1983). Concentrations downstream were progressively reduced, but they never reached control site levels. The highest concentrations of zinc in both Spring Creek and Prickly Pear occurred in July, the period of highest discharge, and October, the period of lowest discharge. Consequently it is not surprising that discharge values and zinc concentrations at sites 012 and 018 did not correlate strongly ($r = 0.53$ and $r = 0.43$, respectively).

Copper responded similarly to zinc (Figure 7, Table 2). Variations in concentrations between sample periods within the same sites were not pronounced. Impact site (013) concentrations ranged from 25 to 37 µg/l, approximately twice the control and final recovery site concentrations. July concentrations were slightly higher than those of other seasons (Table 2). Correlation coefficients for copper concentrations and discharge values for Stations 012 and 018 were $r = 0.11$ and $r = 0.67$, respectively.

No consistent correlation with discharge (positive or negative) was noted for these three metals at the other stations. Spring Creek (012) concentrations of all three metals correlated positively with discharge, but possibly this was extraneous because of the small number of paired data points.

HYDROLOGY

Discharge estimates from field measurements and USGS provisional data (Figure 8, Table 3) show that flow was approximately two times greater in July 1982 than during the other three periods. Flow during the last three sampling periods was essentially uniform and ranged from 38 to 42 cfs at the USGS gauge downstream from site 018.

MACROINVERTEBRATES

Fifty-two macroinvertebrate taxa were collected in Prickly Pear Creek from samples taken from July 18 to 26, 1982, from December 21 to 23, 1982, from April 7 to 9, 1983, and from October 11 to 13, 1983. Estimates of Shannon-Wiener diversity (H'), Evenness (J) and Simpson's Dominance (D) are provided in Table 4 for comparison purposes.

Control Zone (Station 011)

Thirty-nine taxa were collected from the riffles in the control zone during the four sampling seasons. This station consistently provided higher mean total numbers of individual organisms per sample and higher mean and total number of taxa per season than all other sampling stations (Table 4 and Figures 9 and 10).

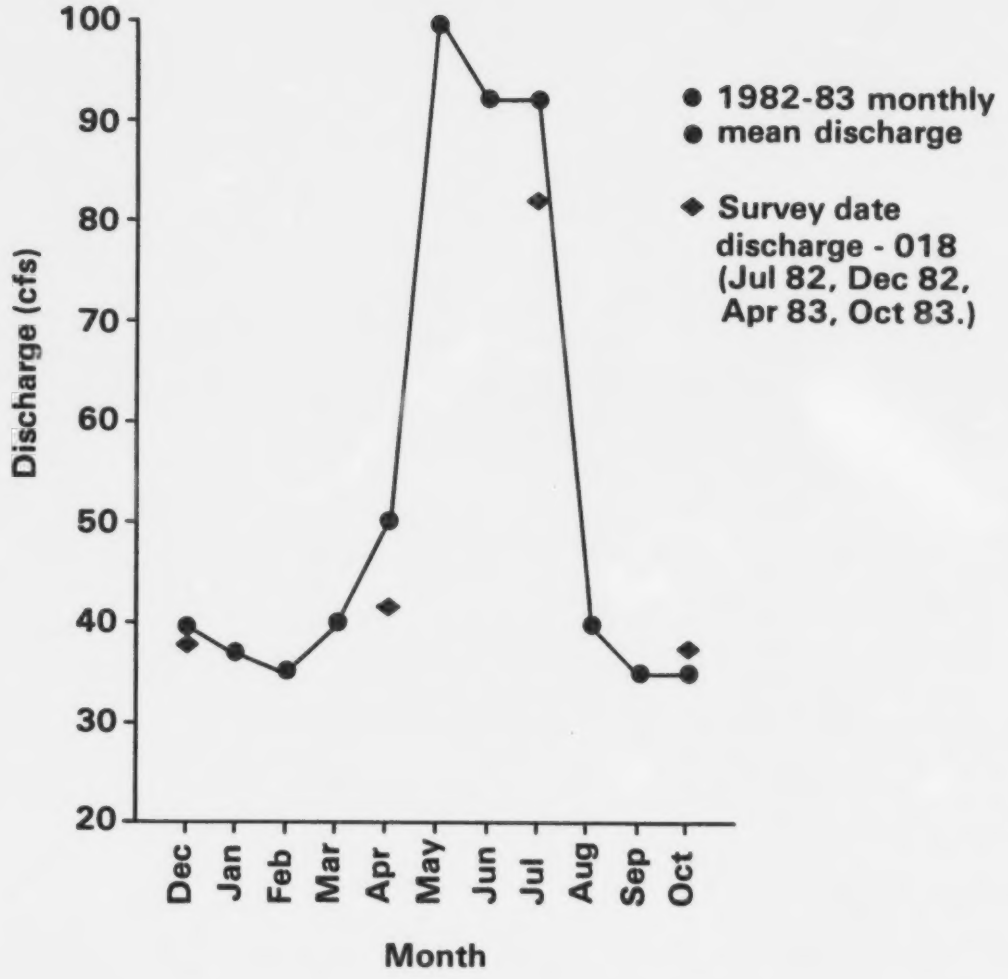

Figure 8. Mean monthly discharge for Prickly Pear Creek, Montana, from December 1982 through October 1983, and measured discharge at the USGS gauge downstream from station 018 during each survey period.

TABLE 3. DISCHARGE ESTIMATES AND USGS DATA FOR PRICKLY PEAR CREEK AND SPRING CREEK DURING THE FOUR SAMPLING PERIODS

Date	011	012	013	014	018	Gauge
July 1982	29	5	29	41	76	82
December 1982*	14	1	14	20	39	39
April 1983*	15	2	15	22	42	42
October 1983	11	1	10	18	37	38

*Site discharge extrapolated from USGS gauge value and measured July and October data.

Thirty-two taxa were collected from the riffle at Station 011 during July when the flow was greatest (Figure 9). The ubiquitous Baetis tricaudatus was very common, comprising 38 percent of the total numbers of individuals at this site. Other common taxa (6 percent to 30 percent relative abundance) at this site included the mayfly, Epeorus longimanus, and members of the midge subfamily, Orthocladiinae.

The spring, pre-runoff sampling (April) produced both the highest total number of taxa at 37 (Figure 9) and the highest mean number of taxa per sample at 29. The highest mean number of individuals per sample encountered during the study (n = 774) (Figure 10) were collected at this site during April. The most common organism collected in April was the filter feeding caddisfly, Arctopsyche grandis, which comprised 22 percent of the total invertebrate numbers at this site. Other common taxa in the spring included the mayfly, Baetis tricaudatus, with a mean relative abundance of 15.8 percent, and midges of the subfamily, Orthocladiinae at 10.9 percent, Glossosoma sp. at 9.3 percent, and Ephemerella tibialis at 8.2 percent.

The pattern of results for December was similar to that observed in April,

TABLE 4. MEAN INVERTEBRATE COMMUNITY INDICES FROM PRICKLY PEAR CREEK DURING THE FOUR SAMPLING PERIODS
(Coefficients of variation [percent] are noted in parentheses).

Parameter	July 1982				December 1982				April 1983				October 1983			
	011	013	014	018	011	013	014	018	011	013	014	018	011	013	014	018
Mean Count	411 (53)	130 (51)	103 (86)	226 (15)	578 (21)	238 (17)	171 (34)	230 (23)	774 (10)	460 (9)	556 (15)	516 (8)	298 (17)	219 (24)	126 (33)	76 (26)
Richness	21 (36)	15 (14)	10 (43)	19 (8)	27 (10)	15 (17)	13 (23)	16 (19)	29 (17)	19 (20)	16 (10)	22 (16)	20 (16)	11 (6)	15 (26)	9 (26)
Diversity (H')	2.82 (12)	2.44 (5)	2.48 (18)	2.92 (7)	3.36 (4)	2.59 (8)	2.90 (11)	3.12 (7)	3.62 (3)	2.81 (13)	2.40 (12)	2.97 (9)	3.43 (8)	2.08 (18)	3.15 (17)	2.68 (15)
Evenness (J)	0.67 (9)	0.64 (9)	0.79 (11)	0.69 (5)	0.71 (5)	0.66 (5)	0.78 (10)	0.79 (2)	0.75 (5)	0.66 (7)	0.60 (12)	0.67 (7)	0.79 (4)	0.60 (18)	0.81 (13)	0.84 (4)
Dominance (D)	0.77 (5)	0.69 (5)	0.77 (9)	0.80 (6)	0.84 (2)	0.73 (5)	0.81 (7)	0.84 (3)	0.88 (1)	0.80 (6)	0.65 (12)	0.74 (9)	0.86 (4)	0.62 (18)	0.83 (12)	0.82 (7)

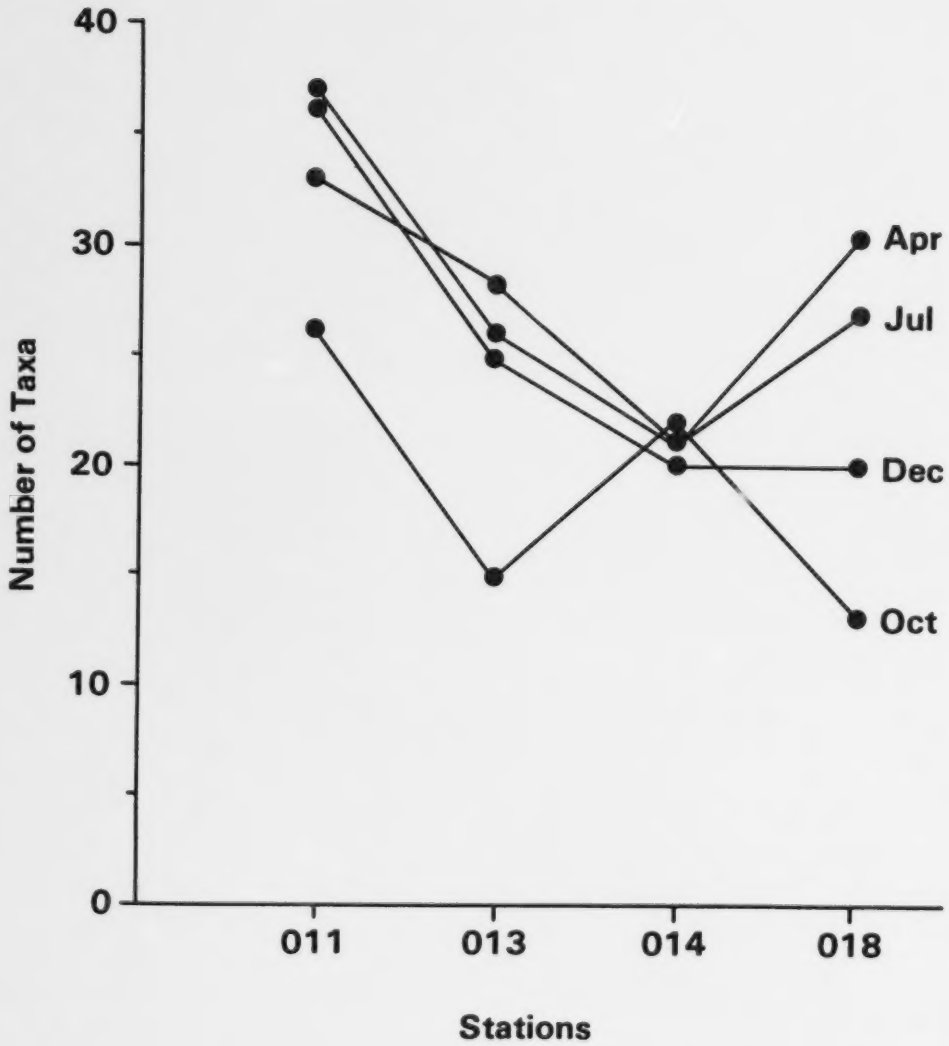

Figure 9. Total number of taxa collected at each station during the four survey periods.

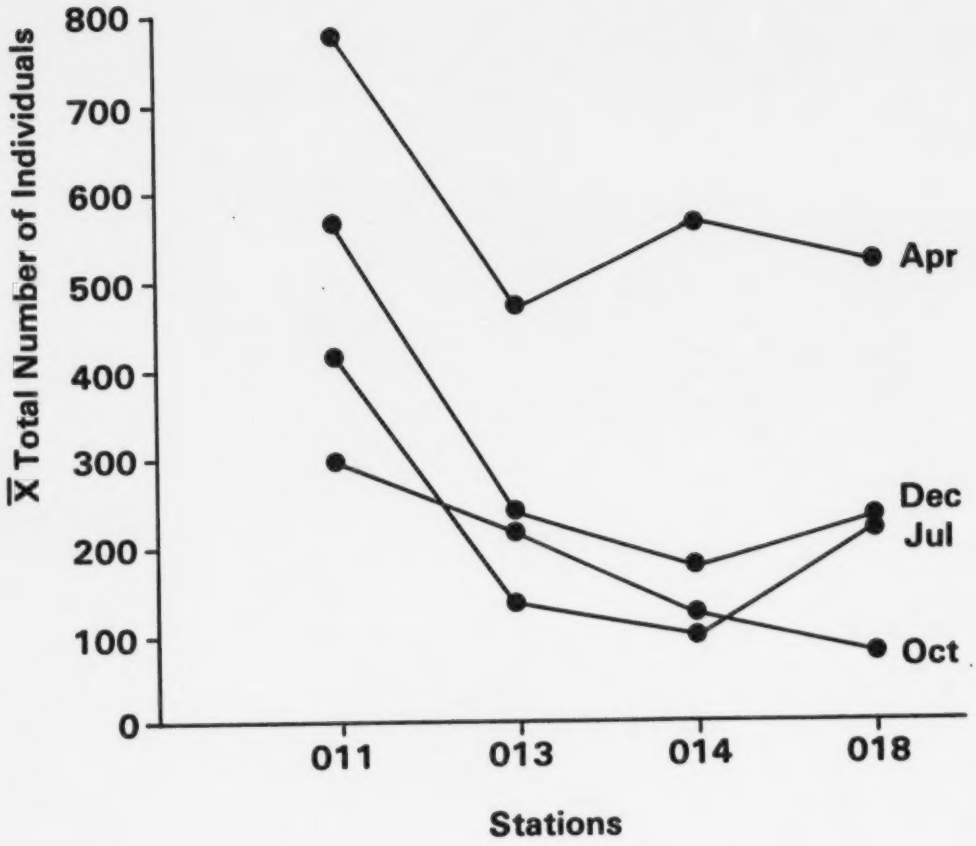

Figure 10. Mean total number of individuals collected at each station during the four survey periods.

although the mean total number of individuals per sample dropped by approximately one-third (Figure 10). Several rare or occasional stoneflies captured in April were not observed in December. The composition of the dominant functional groups changed little from December to April.

The macroinvertebrate community at Station 011 appeared most depressed during fall (October) sampling. The mean total number of individuals per sample was down approximately 60 percent from the spring (Figure 10), and total taxa (Figure 9) and the mean number of taxa per sample were reduced by about one-third. Merrit and Cummings (1984) suggest that this may be a natural seasonal occurrence caused by recent adult emergence and by the inability of the PIBS net mesh size to retain minute nymphal instars. Nine taxa were found at Station 011 during the study that were not collected at any other downstream station.

Spring Creek (012)

In July (1982) Spring Creek (012) was sampled to ascertain the presence or absence of fauna. Only five taxa and a total of nine organisms were collected from five replicate box samples in Spring Creek. These included Orthocladiinae midges and a single stonefly (Chloroperlidae), the caddisfly, Arctopsyche grandis, the crane fly, Tipula sp., and the water mite, Sperchon sp. The low number of invertebrates in Spring Creek reflect the extremely disturbed nature of the watershed and the concomitant elevated metal levels.

Impact Zone (Stations 013 and 014)

Thirty-three taxa were collected during the four sampling seasons at Station 013. The total number of taxa were relatively uniform at this station

during April, July, and December. However, during October the total number of taxa was substantially reduced at Station 013, and differences in the number of taxa between control Station 011 and impact station were most pronounced during the October sampling (Figure 9). As was the case at control site 011, the mean number of individuals per sample was highest in April (n = 460). December, October and July values did not differ greatly in terms of numbers of individuals (Figure 10, Table 4).

Two species, Baetis tricaudatus and Arctopsyche grandis, predominated at this station during all sample seasons. Combined, they made up 54 percent of the total standing crop in July, 65 percent in December, 49 percent in April, and 72 percent in October. The only other organisms that contributed substantially were the gatherer, Antocha sp. which made up 24 percent of the total standing crop in April, the Diamesinae midges, and the caddisfly, Brachycentrus sp., in July.

Twenty-eight taxa were collected during the four seasons at Station 014, but unlike Station 013 no difference in total taxa was evident on a seasonal basis (Figure 9). As was the case on the upstream stations, the average total number of individuals was greatest during April, and exceeded total numbers collected during other seasons by approximately threefold (Figure 10).

During July, the total number of taxa decreased from 28 at Station 013, to 20 at Station 014, when 8 of the 11 upstream mayfly species were eliminated. Mean total numbers of invertebrates collected dropped from 130 at Station 013 to 103 at Station 014. Three out of five replicates at Station 014 contained fewer than 100 total animals. Orthoclad midges were very common at this site (32 percent total relative abundance). Brachycentrus sp., the crane fly, Antocha sp. and the snipe fly, Atherix variegata, were also common. In all

seasons except October, Station 014 had the lowest total taxa and the lowest mean number of taxa per sample of any station sampled (Figure 9 and Table 4). The reasons for the October increase in the total number of taxa per sample at Station 014 is unknown.

Recovery Zone (Station 018)

The total number of taxa collected during the four seasons increased to 31 in the recovery station. Seasonal differences in the number of taxa and the mean total number of individuals was the most pronounced at this site of any station sampled during the study (Figures 9 and 10).

The total number of taxa collected during the July sampling period was 26. However, some stonefly and mayfly species present in the control zone and absent from impact stations did not reappear here (e.g., Ephemerella inermis and Doroneuria theodora). This may be a function of downstream physical changes in the stream (e.g. substrate, flow). Relative abundances of the orthoclad midges fell to 25 percent of the total invertebrate densities. Baetis tricaudatis increased to 28 percent relative abundance from 4 percent within the impact zone. Brachycentrus sp. and Atherix variegata remained common. The number of taxa for December varied little between 014 and 018, but the mean total number of organisms per sample was slightly greater at Station 018 (Figure 10 and Table 4). During October, both the total number of taxa and mean total number of individuals was the lowest of any station sampled during the entire study.

V. DISCUSSION

The concept that metal concentrations originating from mine tailings are altered relative to flow is not new. However, pollutant response to runoff, flow, and season is not well understood. Temperature, ground saturation, composition of tailings, exposure period, and other factors act collectively to produce varying amounts of leachate during runoff events at different times of the year. Even less well understood may be the aquatic ecosystem response pollutants, especially as communities succeed each other throughout the year. The goal of this study was to examine the relationships of the biota and pollutant (metals) variations to fluctuations in discharge during four seasons. The main emphasis of the goal was to describe the seasonal variations in macroinvertebrate communities in Prickly Pear Creek and to provide a data base against which future investigations could be compared. In Prickly Pear Creek community response was assumed to be related directly to toxic levels of metals. Metals in this stream are contributed primarily from leachate supplied via Spring Creek. This contribution varies presumably as a result of changes in discharge levels in both creeks. Biological response is also related directly to community tolerance which changes throughout the year because of natural succession and because of exposure of different invertebrate life stages to pollutants. Our principal hypotheses were that water column metal concentrations in Prickly Pear Creek were related to discharge, and that instream toxicity and resultant community responses correspond to seasonal variations in both

discharge and metal concentrations. Essential to the hypotheses are four assumptions: (1) metal concentrations in the water column are either (positively or negatively) correlated to discharge; (2) instream toxicity is directly related to metal concentration in the water column; (3) biological responses to instream toxicity are reflected by the macroinvertebrate communities, and their responses can be measured by analyzing the communities; and (4) discharge is sufficiently different during the four sampling periods to enable the establishment of relationships among discharge, stream chemistry, and composition of macroinvertebrate assemblages.

That concentrations of metals in Spring Creek and the resultant levels in Prickly Pear Creek change between seasons is shown by the data (Table 2). However, an obvious feature of these data is the very high concentrations of cadmium, silver and arsenic during July as compared to concentrations during the other seasons; consequently, one must suspect the integrity of the July data. Values presented for these metals (and for lead) approach the detection limits of the instrument used for these analyses (Alexander and McAnulty, 1981) and this may account for the seemingly abnormally high values. La Point et al. (1983) point out that most of the variance in these data were attributable to analytical variability among replicates. Within-replicate variability for total cadmium, silver and arsenic was 80 percent, 56 percent, and 80 percent, respectively (La Point et al., 1983). Variance components for lead were not presented. The analytical capability of the ICP for analysis of copper and zinc, however, appears adequate for levels reported, as they are well above the detection levels (Alexander and McAnulty, 1981). La Point et al. (1983) reported that differences among stations accounted for 100 percent of the total zinc variability during the July sampling and for 94 percent of the variability in

copper concentrations for this same period. Considering only the zinc and copper data then, the only obvious trends that emerge are that zinc in Prickly Pear Creek, reached its highest concentration during the period of lowest discharge (October 1983), whereas copper concentrations were highest at the impact station during the December 1982 period of stable flow. Concentrations of both metals in Spring Creek were greatest during the July 1982 period of high discharge. The lack of consistent correlation between metal concentration and discharge may be attributable primarily to variations in the amount of rain that fell in tributary watersheds that feed Prickly Pear Creek. Because each tributary has received differing amounts of disturbance, and because each produced either a dilution effect or an increase in metals leached during events, small rainstorms that affect flow at the USGS gauge downstream from Station 018 may not necessarily have produced a consistent increase or decrease in metals at all stations on Prickly Pear Creek.

Toxicity data from Baker and Baldigo (1984) showed that Spring Creek metal concentrations exhibited significant temporal variability. Over a 10-day period, concentrations of dissolved zinc and copper varied by as much as 100 percent. Resultant increases in Ceriodaphnia sp. and Pimephales promeles toxicity (chronic and acute) were strongly correlated to increases in metal concentrations. Changes in metal concentrations in Spring Creek were sometimes, but not always, associated with precipitation events, and were possibly modified by occasional freezing conditions.

Hydrologic flow during our study period did not provide a good discharge gradient, hence, expected changes in chemical and toxic conditions were not well defined. Studies of seasonal variability might better be conducted during

the months of January, April, May, June and August, or September for more predictable flow character as based on historical information (USGS, 1980).

Macroinvertebrate community response, on the whole, was predictable, with well-defined control, impact, and recovery sites. Reductions in the number of individuals, diversity, evenness, and dominance were evident during all four seasons at the impact sites where concentrations of zinc and copper were consistently highest (Tables 2 and 4; Figures 6, 7, 9 and 10). Trends toward recovery at Station 018 were evident, but recovery to control station type communities was not complete. This was undoubtedly more a function of habitat changes than of toxic influence.

The pattern of changes in the number of taxa across stations was similar during April, July, and December (Figure 9). In each instance the control and recovery zone stations supported the highest number of taxa and the second impact zone station (014), the fewest. For reasons that aren't clear this pattern did not hold during October, when the number of taxa at Station 014 approached those at the control station, and density was markedly reduced at Station 013 and 018. In terms of numbers of individuals, the impact at Station 013 and 014 is very apparent. Evidence of recovery at Station 018 was apparent during all seasons except October when numbers of individuals showed a progressive reduction downstream.

The deviation in seasonal stream metal concentrations because of undefined factors in Prickly Pear Creek was evident. Whether the differences were significant cannot be ascertained by the current study. Biological systems are known to vary naturally on a seasonal basis. It is difficult to precisely define natural biological variability, and extremely difficult to integrate into this variability the effects of a variable toxic discharge on an aquatic

system. The present study shows a trend for correlation between discharge and cadmium concentrations in the impact and control sites of Prickly Pear Creek, however, the cadmium data for July 1982 are suspect. This trend was not consistently apparent for other metals or at other stations. It is evident that a more intensive study would be necessary to clarify relationships among discharge, metal concentration, instream toxicity and community response. Such a study should incorporate consistent water quality analytical methods with sufficient sensitivity, accuracy and precision to reliably measure levels of toxic metals encountered in Prickly Pear and Spring Creeks. The macroinvertebrate sampling conducted during this study was adequate and additional sampling using the same methods should be followed in future studies. Maximum information for effort expended would probably be obtained by sampling during the spring, summer, or winter. Fall sampling produced somewhat anomalous results that cannot be easily explained, and may not depict a truly representative pattern of biological responses to toxicity. Discharge measurements taken at the time each site is sampled chemically and biologically would provide reliable data for future correlations. The sampling locations described in this study are adequate to demonstrate spatial variations in water quality, hydrology and the biota and they should be maintained in future studies for consistency in the data base.

VI. CONCLUSIONS

Toxic metals originating from abandoned mine tailings in the Corbin and Spring Creek drainage reached Prickly Pear Creek via Spring Creek near Jefferson City, Montana. Principal metals of concern were cadmium, copper and zinc because their concentrations in Prickly Pear Creek waters exceeded the national water quality criteria limits for the protection of aquatic life. Elevated levels of these three metals were present in Prickly Pear Creek waters during four seasons in the impact zone immediately downstream from the Spring Creek and Prickly Pear Creek confluence. Concentrations downstream in the recovery zone approached, but did not quite reach, levels in the unimpacted control zones.

Stream discharge during the winter, spring and fall sampling periods was nearly uniform within each station. During the summer sampling, however, discharge levels were approximately twice those reported during other periods. During this high flow period, the highest concentrations of the three metals in Spring Creek water were recorded. Cadmium and zinc concentrations reached their next high levels during October 1983, which was a period of low, stable flow. No pronounced trends in copper concentration were apparent on a seasonal or flow related basis.

Macroinvertebrate communities were definitely affected by the high levels of metals in the impact zone. Reduction in numbers of individuals, numbers of taxa and related parameters were apparent during all seasons in the reach

downstream from the Spring Creek discharge. Recovery of communities to control station levels was not complete, but this was judged to be a function of different habitats in the downstream reaches rather than a direct impact of metals. October data were somewhat anomalous in that the second impact site showed an increase in total number of taxa and the recovery site showed a reduction in number of taxa. In terms of numbers of individuals, the fall data were also somewhat anomalous as total numbers of individuals progressively decreased downstream, reaching their lowest densities in the recovery zone.

Additional studies would be needed to clarify relationships among discharge, seasons, water quality and the biota. Refinement of hydrological measurements, use of consistent techniques for metals analyses and some adjustment of sampling periods would be required to assure a high probability of success in future studies.